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Performance Assessment and Regulatory Compliance

Description of Performance Assessment

Performance assessment (PA) is defined in the United States by the Environmental Protection Agency (EPA) and the Nuclear Regulatory Commission (NRC) regulations as a process to be used in estimating the long-term performance of deep geologic disposal sites for high-level and transuranic radioactive waste. Although specific regulatory requirements differ for individual projects (e.g., the Waste Isolation Pilot Plant and the potential repository at Yucca Mountain), the overall approach to PA is similar in repository programs both within the U.S. and internationally. PAs provide a quantitative estimate of the overall performance of the disposal concept, taking into account the uncertainty associated with the behavior of engineered and natural systems over very long periods of time. Results are compared to regulatory limits, in terms of annual radiation doses to hypothetical future humans or cumulative radionuclide releases from the site, and uncertainty in those results is evaluated as part of the decision-making process before the site is approved for operation.

Sandia Capabilities in Performance Assessment

Performance assessments begin with the selection of a disposal concept (such as a mined geologic repository in a specific rock type) and the preliminary selection of one or more sites for evaluation. Physical characteristics of sites must be characterized sufficiently to allow identification of the features, events, and processes most likely to effect performance, and to support numerical modeling of important aspects of the system such as waste mobilization and groundwater flow. Early iterations of system-level modeling allow identification of areas where further data collection is needed to support more detailed analyses, and subsequent iterations throughout the process of characterizing the site allow for sensible prioritization of research activities and informed decisions regarding the suitability of the site. Ultimately, if the site is suitable, information gathered during site characterization will support a PA that will meet regulatory expectations for defensibility and traceability, and will become the cornerstone of a licensing decision.

Sandia National Laboratories has expertise in the complete PA process that includes:

Identification of Relevant Features, Events, and Processes (FEPs)

Not all potentially relevant FEPs will have a sufficient impact on performance to warrant including in computational models, and resources should be focused on those that matter. Careful identification of the relevant FEPs, screening evaluations to determine which FEPs must be included in the full modeling effort, and documentation of the technical basis for the exclusion of FEPs is a fundamental step in PA that assures confidence in the completeness of the analysis.

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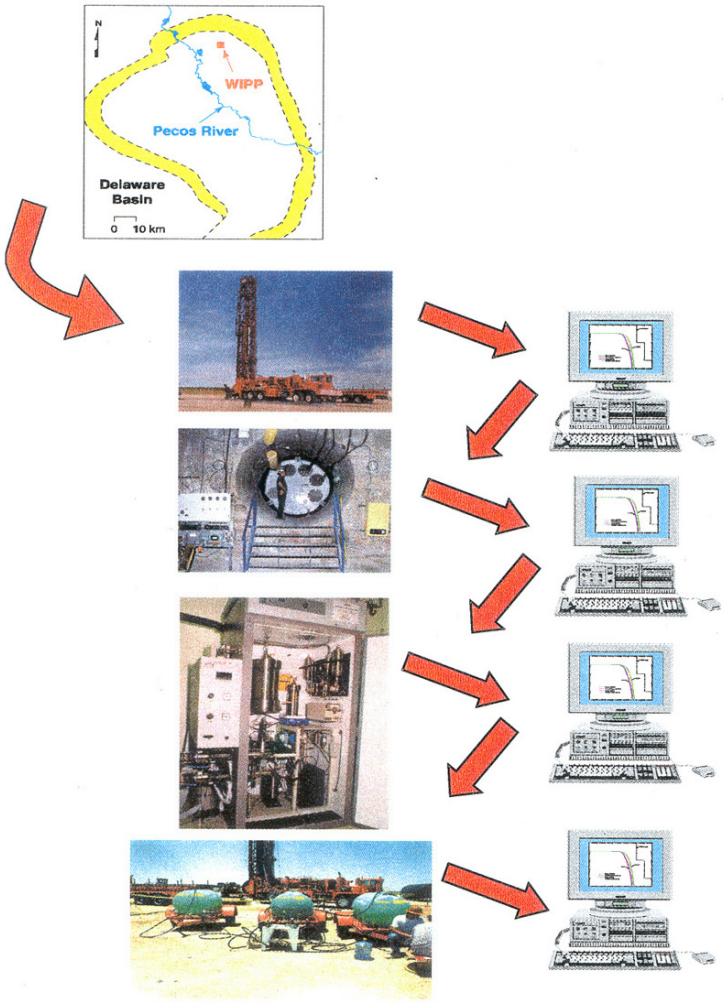
Scenario Selection

Pragmatically, computational models can only address a small number of the essentially infinite number of future states of the system that could be imagined. Scenarios for modeling must be selected so that they are appropriately representative of the full range of plausible future states, including the relevant FEPs, without resulting in an unworkably large number of discrete cases to be modeled.



Using Iterative Performance Assessment to Guide Data Collection During Site Characterization

Model Development

Computational models must be developed that simulate the major components of the system, including the evolution of the engineered and geologic barriers through time. These models must capture all important uncertainties in the system, either explicitly or with defensibly bounding assumptions, they must meet the expectations of the technical review community, and they must be computationally efficient to be effective in the overall PA. Typically, PA models must represent some level of abstraction or simplification from detailed process models developed by experts working in the individual component areas because such models are rarely efficient enough to meet the demands of system-level simulation. Both detailed process models and efficient PA implementations must be developed for processes such as waste form degradation, radionuclide mobilization, groundwater flow, and radionuclide transport.

Characterization of Uncertainty in Models and Data

Site characterization and experimental programs can reduce uncertainty, but it cannot be eliminated. Uncertainty must be included in the PA, either through the consideration of alternative scenarios that can be weighted by the probability of their occurrence (e.g., human intrusion, igneous disruption), through the explicit consideration of alternative conceptual models for important processes, or through the development of probability distributions that characterize uncertainty in the data used to develop parameter values used in the models.

Code Linkage and System-Level Monte Carlo Modeling

System-level simulations require linking computer models for individual components into an overall model that allows automated data flow and fully scripted simulations of the complete system. System-level modeling must ensure traceability and reproducibility of results from the large number (hundreds to thousands) of Monte Carlo simulations used in a full uncertainty analysis.

Uncertainty and Sensitivity Analysis

Monte Carlo analyses using large numbers of simulations of system performance with different sampled values of uncertain input parameters can be analyzed using a variety of statistical techniques (e.g., step-wise linear regression analysis) to identify and rank those models and parameters to which overall performance is most sensitive. Examination of the distribution of calculated results provides a measure of the level of confidence associated with the specific performance measure (e.g., the mean) that is used for assessing regulatory performance.

System Prioritization

Uncertainty and sensitivity analyses can be used to identify those aspects of the model where reductions in uncertainty will result in the greatest changes in overall performance. Information about the cost and time required for activities planned to reduce uncertainty in specific areas can be combined with results of PA sensitivity analyses to provide the basis for risk-informed project management. Resources can be allocated to those experimental and field programs that will have the impact on overall performance.

Demonstrating Regulatory Compliance

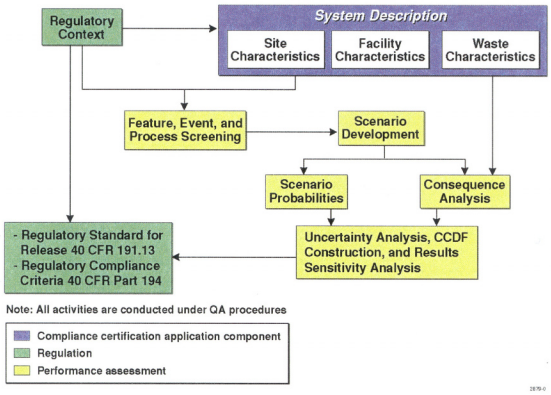
PAs that support a licensing decision must meet both technical and regulatory criteria for completeness, sufficiency, traceability, and reproducibility. Supporting data and models must be qualified, software must be appropriately verified and validated, and all calculations must be done in a controlled and reproducible environment.

Sandia Accomplishments in Performance Assessment

Sandia has had a major role in performance assessments for radioactive waste disposal since the field first developed in the late 1970s. Specific projects include:

Sub-Seabed Disposal of Radioactive Waste (Feasibility of Disposal of High-Level Radioactive Waste into the Seabed)

This project was sponsored by the Nuclear Energy Agency of the Organization for Economic Cooperation and Development (1976-1988). Sandia had lead responsibility for performance assessment for the international project and was a key participant in the feasibility evaluation.



Methodology for Performance Assessment of the WIPP

Waste Isolation Pilot Plant

Sandia performed iterative performance assessments for the WIPP between 1989 and 1992. Each of these preliminary PAs included sensitivity analyses identifying parameters with the greatest impact on system-level performance. Results of these PAs were delivered to the Department of Energy (DOE) and were used to guide experimental and design activities. Sandia used the Systems Prioritization Methodology (SPM) in 1994 and 1995 to quantify the effect of all proposed technical activities, including experimental research and design alternatives, on the likelihood of achieving compliance with applicable long-term EPA regulations. The DOE was able to select an optimal combination of activities to achieve a defensible compliance certification application within the allowable time.

Sandia conducted the final performance assessment for the WIPP Compliance Certification Application in 1996, and executed an additional set of PA calculations for the EPA (the EPA Verification Test) to allow the EPA to

test system sensitivity to expanded ranges of uncertainty for selected parameters. These sensitivity analyses provided EPA with additional confidence that the CCA PA was robust and that the site should be certified. Sandia is currently developing PA models and data for use in the required period recertifications of the site.

Greater Confinement Disposal Project

Sandia has conducted PAs since 1989 to advise the DOE on the suitability of the Greater Confinement Disposal (GCD) facility on the Nevada Test Site. PAs for the GCD have evaluated the capability of the site to meet EPA standards for the disposal of transuranic waste.

Idaho National Engineering and Environment Laboratory (INEEL) Spent Nuclear Fuel and High-Level Waste Program

Sandia used PA between 1993 and 1998 to evaluate alternative disposal options for high-level radioactive waste and spent fuel stored at the INEEL and the Hanford Reservation. The purpose of the studies was to assess the likelihood that hypothetical disposal sites could comply with applicable long-term regulations. Performance assessments used data from actual sites as analogs for the hypothetical sites. Sites considered included a bedded salt site (using WIPP as an analog), a granite site (using generic data and site-specific data from the Lac Du Bonnet site in Canada as an analog), and a tuff site (using Yucca Mountain as an analog).

Yucca Mountain Project

Sandia had a key role in designing total system performance assessment (TSPA) methodology for the Yucca Mountain Site Characterization Plan in 1988, and completed iterative preliminary TSPAs for the site in 1990, 1991, and 1993. Since 1995, Sandia has been a partner with Duke Engineering and Services in the Civilian Radioactive Waste Management System Management and Operating Contractors Performance Assessment Department, and has a key role in the 1995 preliminary TSPA and TSPAs to support the 1998 Viability Assessment and 2000 Site Characterization Consideration Report.

Description of Regulatory Compliance

The success of scientific work done in support of repository programs is ultimately judged in terms of regulatory compliance. Does the quality work meet regulatory expectations regarding traceability, transparency, and reproducibility? Is the scientific evaluation complete, and does it provide a sufficient basis for a regulatory decision? Finally, and greatest interest to many participants in the process, is the site in compliance with the quantitative regulatory standards?

Sandia Capabilities in Regulatory Compliance

Sandia has demonstrated expertise in working within a regulatory environment (i.e., in compliance with applicable quality assurance procedures that ensure traceability, transparency, and reproducibility) in both the WIPP and Yucca Mountain projects. All technical work that will support the regulatory decision, from data collection to performance assessment analysis, is done in a controlled environment that ensures that the information will be qualified for use.

Sandia's expertise in regulatory compliance goes beyond designing and implementing effective quality assurance programs, and includes analyzing and interpreting regulations to ensure that the technical products (e.g., performance assessments) are designed from the start to meet regulatory needs. For example, FEP screening work must be planned and executed consistent with regulatory guidance, and the scenarios selected for analysis must meet regulatory expectations with respect to completeness and representativeness. Models and data must be

acceptable to technical staff advising the regulator, and computational analyses must be transparent and reproducible by the regulator as well as by the applicant.

Sandia has been involved in the development of the regulatory framework for radioactive waste disposal since the early 1980s, first as an advisor to the NRC and more recently through its role in reviewing and commenting on proposed EPA and NRC regulations that apply to the WIPP and Yucca Mountain projects.

Sandia's Accomplishments in Regulatory Compliance

Waste Isolation Pilot Plant: Sandia had a key role in the successful Compliance Certification Application (CCA) to the EPA in 1996, providing the scientific basis for the application and conducting the performance assessment that demonstrated compliance with the EPA standard. Aspects of the regulatory interactions included:

- Commenting on proposed EPA regulations and advising the DOE during the EPA's rulemaking process
- Support for DOE and EPA audits of data and models
- Design and execution of the CCA PA consistent with regulatory requirements
- Training of EPA technical staff in the use of PA models
- Public technical exchanges with EPA and stakeholders on all aspects of the scientific program and PA
- Participation in public hearings
- Preparing and documenting responses to all comments from the EPA and stakeholders regarding technical aspects of the PA and its scientific basis
- Support for the EPA in conducting its own set of PA calculations using the Sandia models to verify the CCA results and to test sensitivity to alternative assumptions about models and parameters.

Yucca Mountain Project: Sandia has been involved in supporting DOE in regulatory interactions with the NRC since the late 1980s. Since the publication of proposed EPA and NRC regulatory standards for Yucca Mountain in 1999, Sandia has had a major role in designing the TSPA to ensure that it meets regulatory expectations with respect to the calculation of probability-weighted "expected annual dose." Sandia has also been closely involved in formal technical exchanges between the DOE and NRC that are intended to provide resolution of as many technical issues as possible before submittal of a potential license application in 2002. Emphasis in these exchanges is on the completeness and adequacy of the technical work for its intended purpose and on its defensibility for use in regulatory decision making. Technical exchanges are formal public meetings whose discussions and presentations become part of the regulatory record. Sandia has also participated in DOE audits of data and models used to support the PA with NRC observers present. Both DOE and NRC observer reports of audits also become part of the regulatory record for the Yucca Mountain project.

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